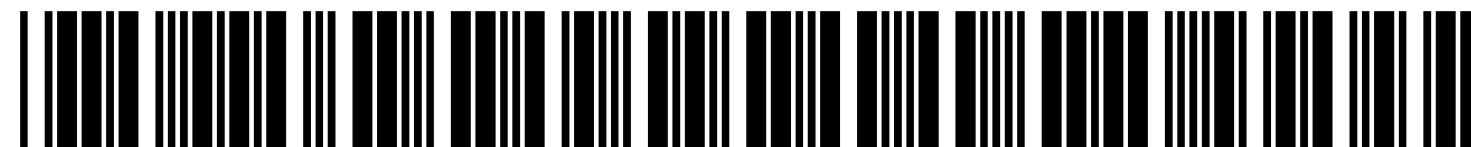

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Nishizawa et al.

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(45) **Date of Patent:** **Aug. 2, 2016**

(54) **SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING THE SEMICONDUCTOR DEVICE**

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CPC ***H01L 23/5226*** (2013.01); ***H01L 21/486*** (2013.01); ***H01L 21/76877*** (2013.01);
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See application file for complete search history.

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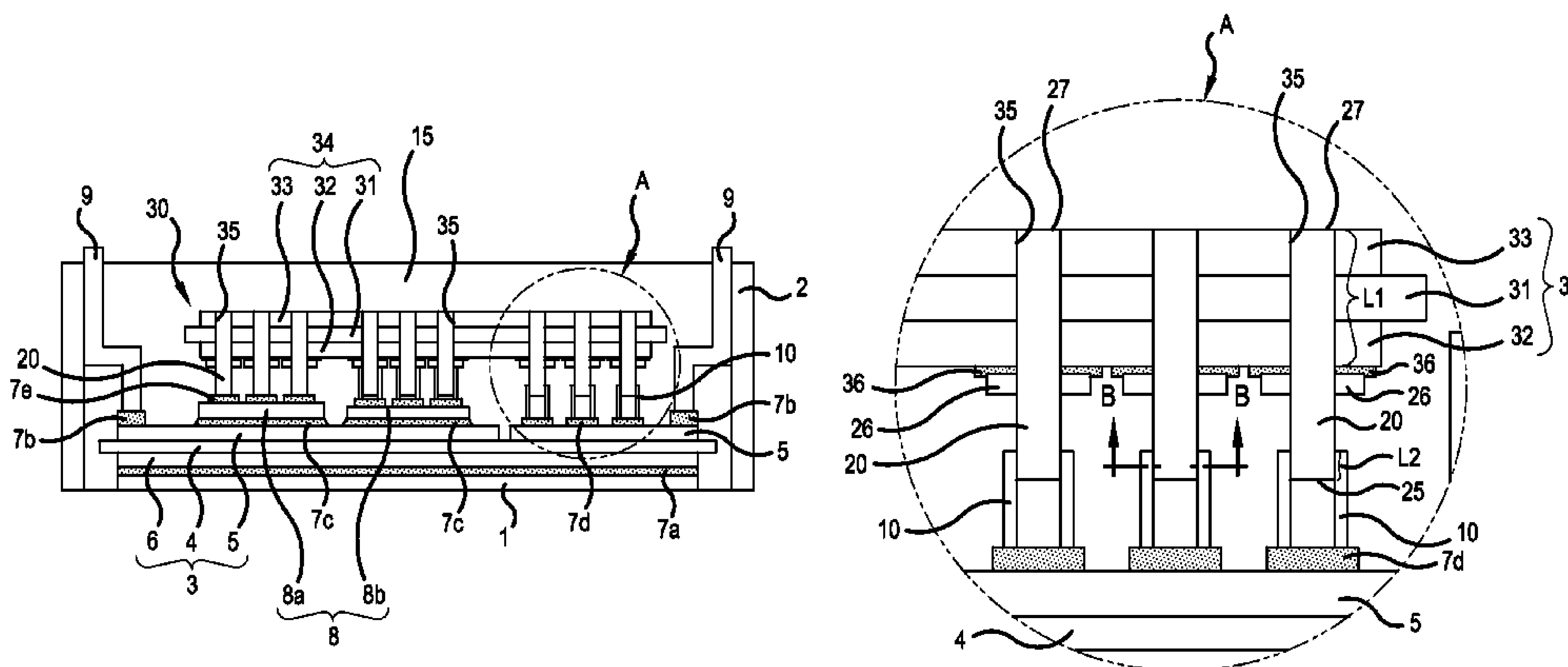
(74) *Attorney, Agent, or Firm* — Rossi, Kimms & McDowell LLP

(57) **ABSTRACT**

A semiconductor device is disclosed in which an implant board and a semiconductor element of a semiconductor mounting board are bonded and electrically connected through implant pins and which can be manufactured with high productivity. Implant pins are bonded to a semiconductor element and/or a circuit pattern of a semiconductor mounting board through cylindrical terminals press-fitted into the other ends of the implant pins. Press-fitting depth L2 of each of the implant pins into corresponding cylindrical terminals is adjustable, so that total length of the implant pin and cylindrical terminal which are press-fitted to each other matches up with the distance between the semiconductor element and/or the circuit pattern on the semiconductor mounting board and an implant board.

11 Claims, 8 Drawing Sheets



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H01L 23/40	(2006.01)
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H01L 25/07	(2006.01)
H01L 23/498	(2006.01)
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H01L 23/433	(2006.01)
H01L 21/48	(2006.01)
H01L 21/768	(2006.01)
H01L 23/24	(2006.01)

(52) **U.S. Cl.**

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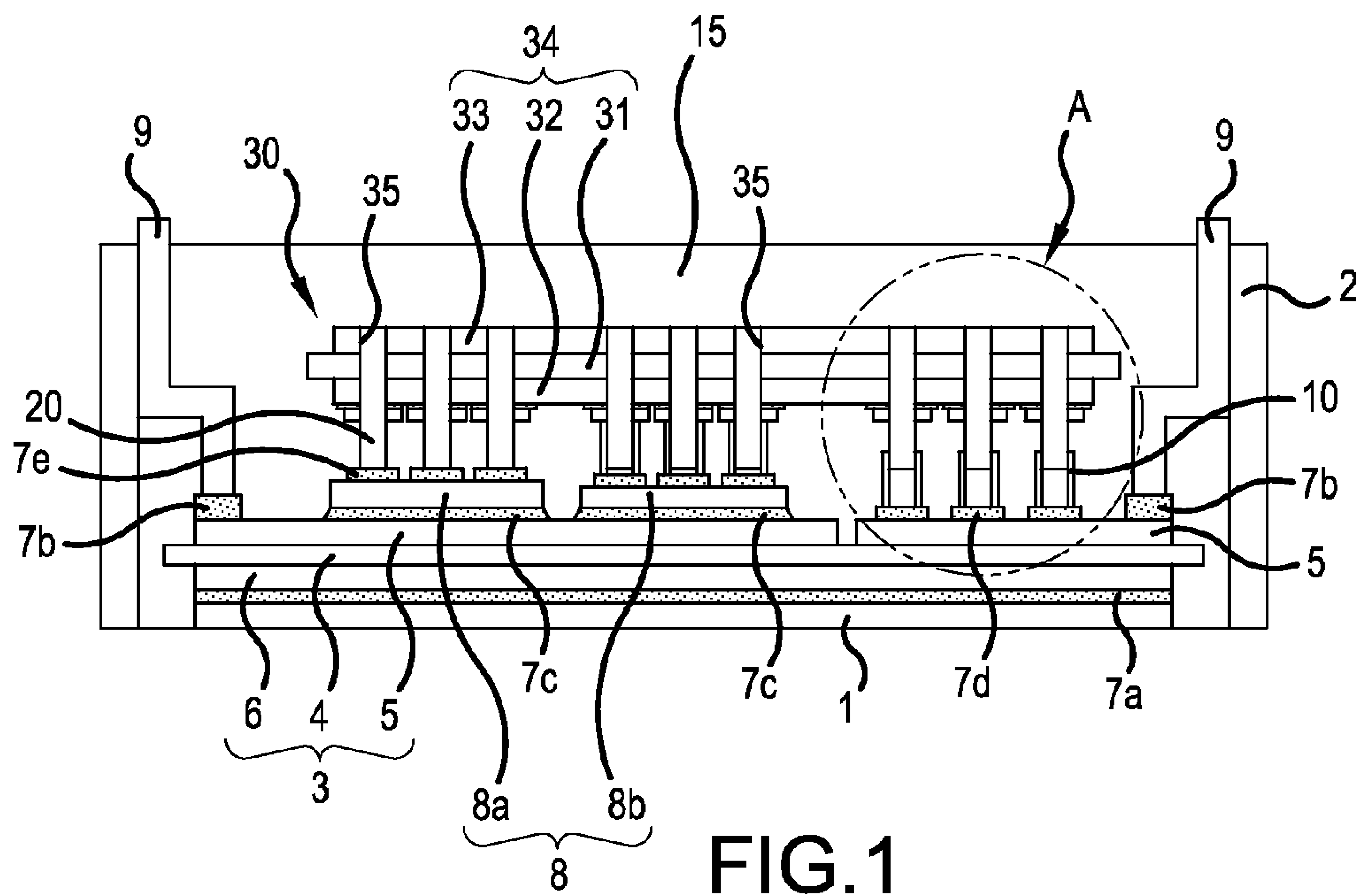

FIG.1

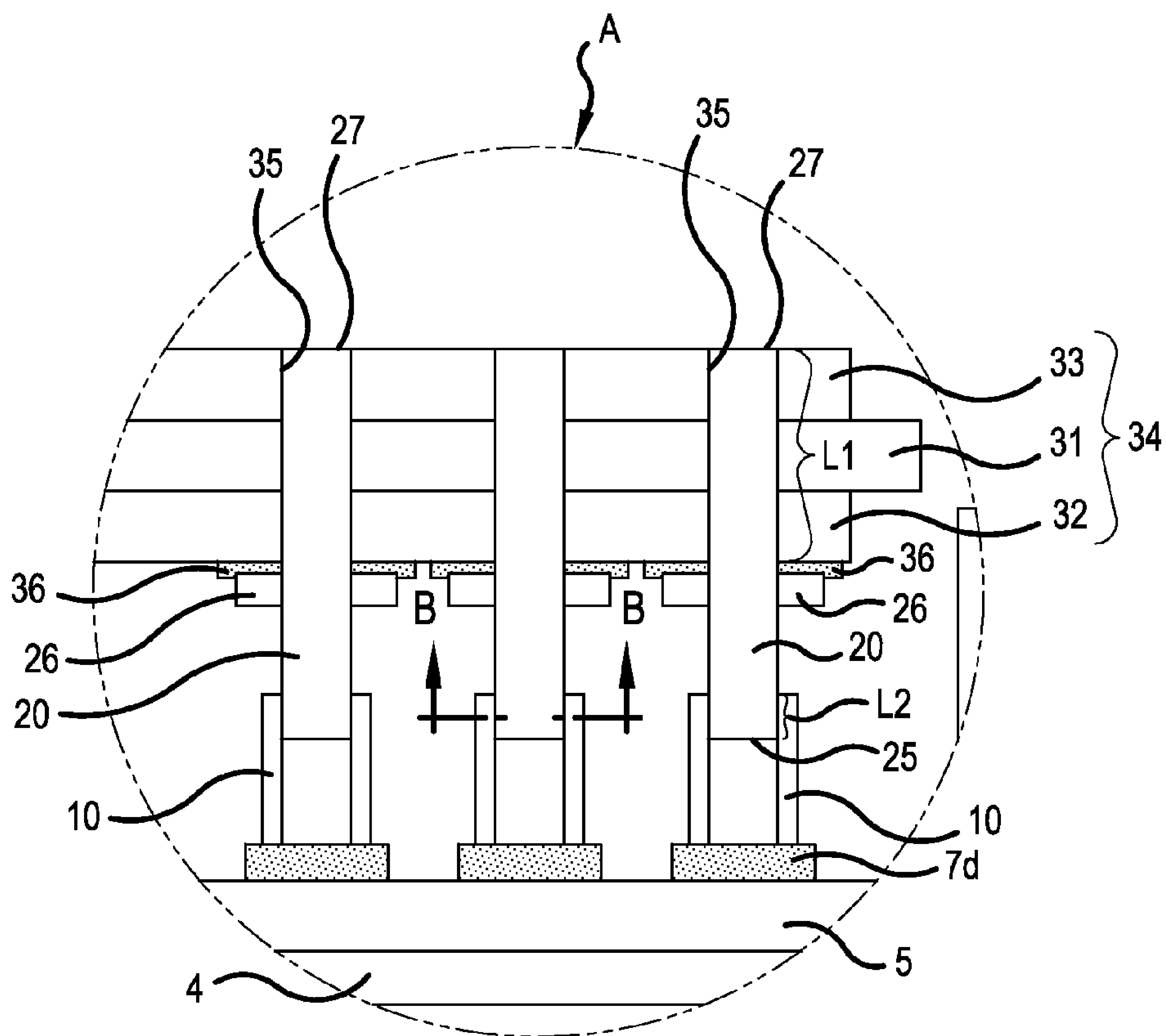

FIG.2

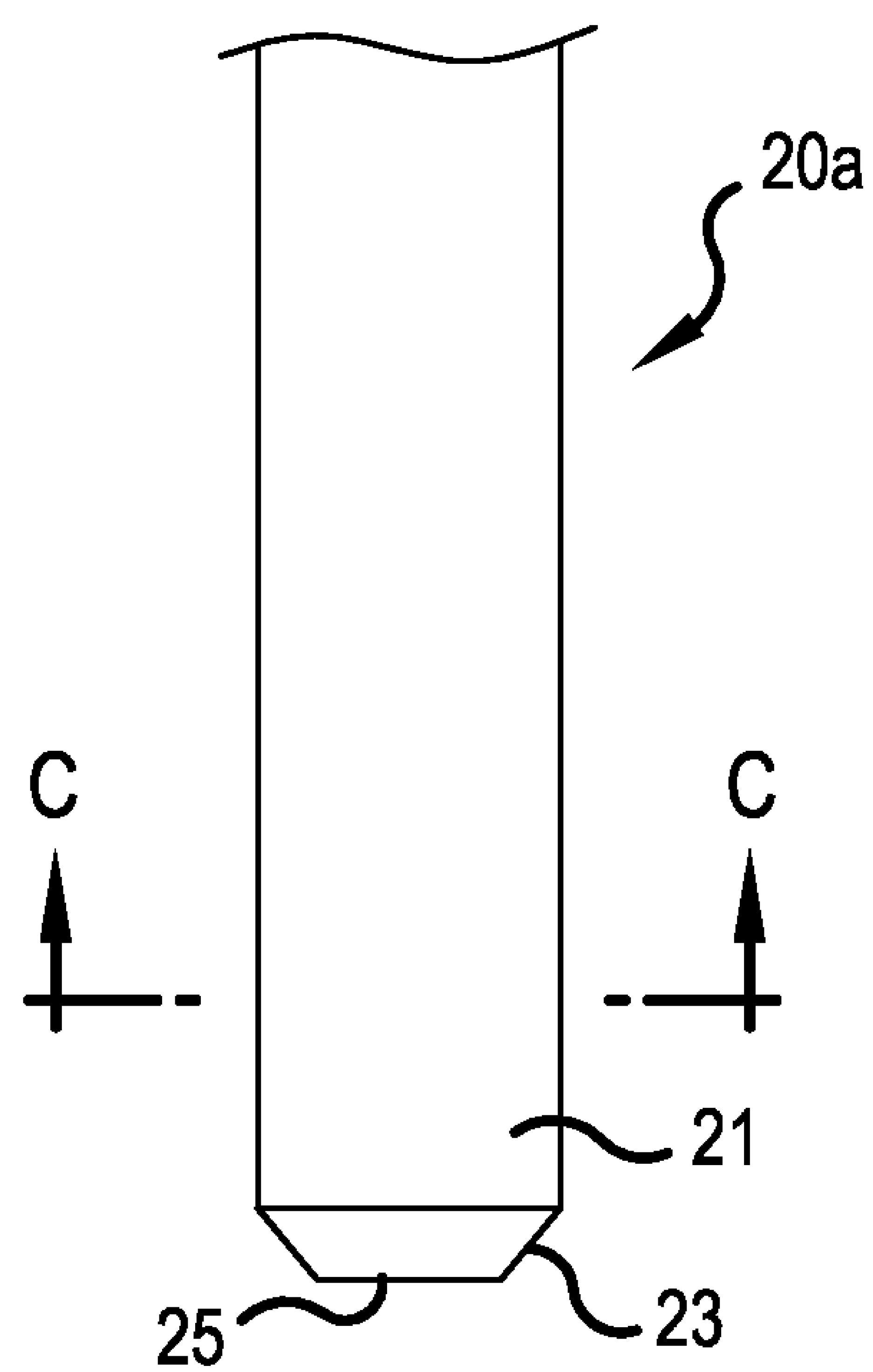

FIG.3(a)

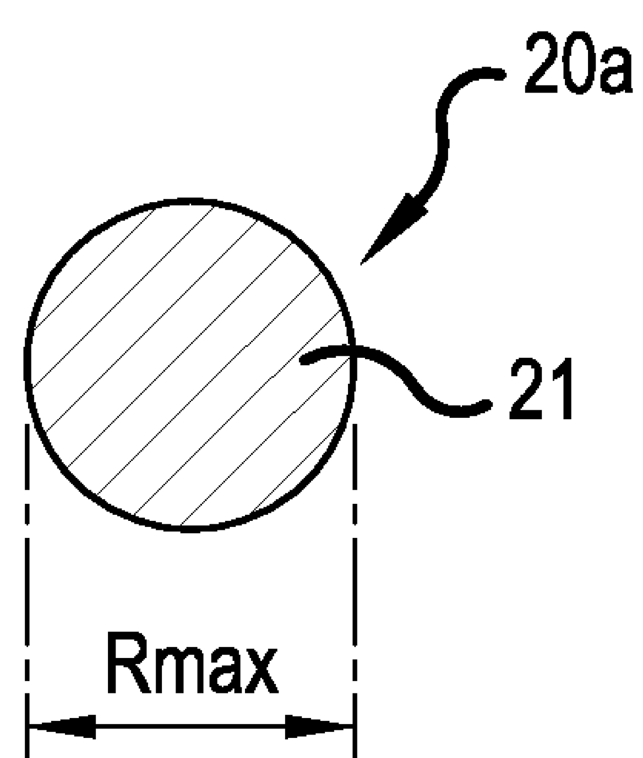

FIG.3(b)

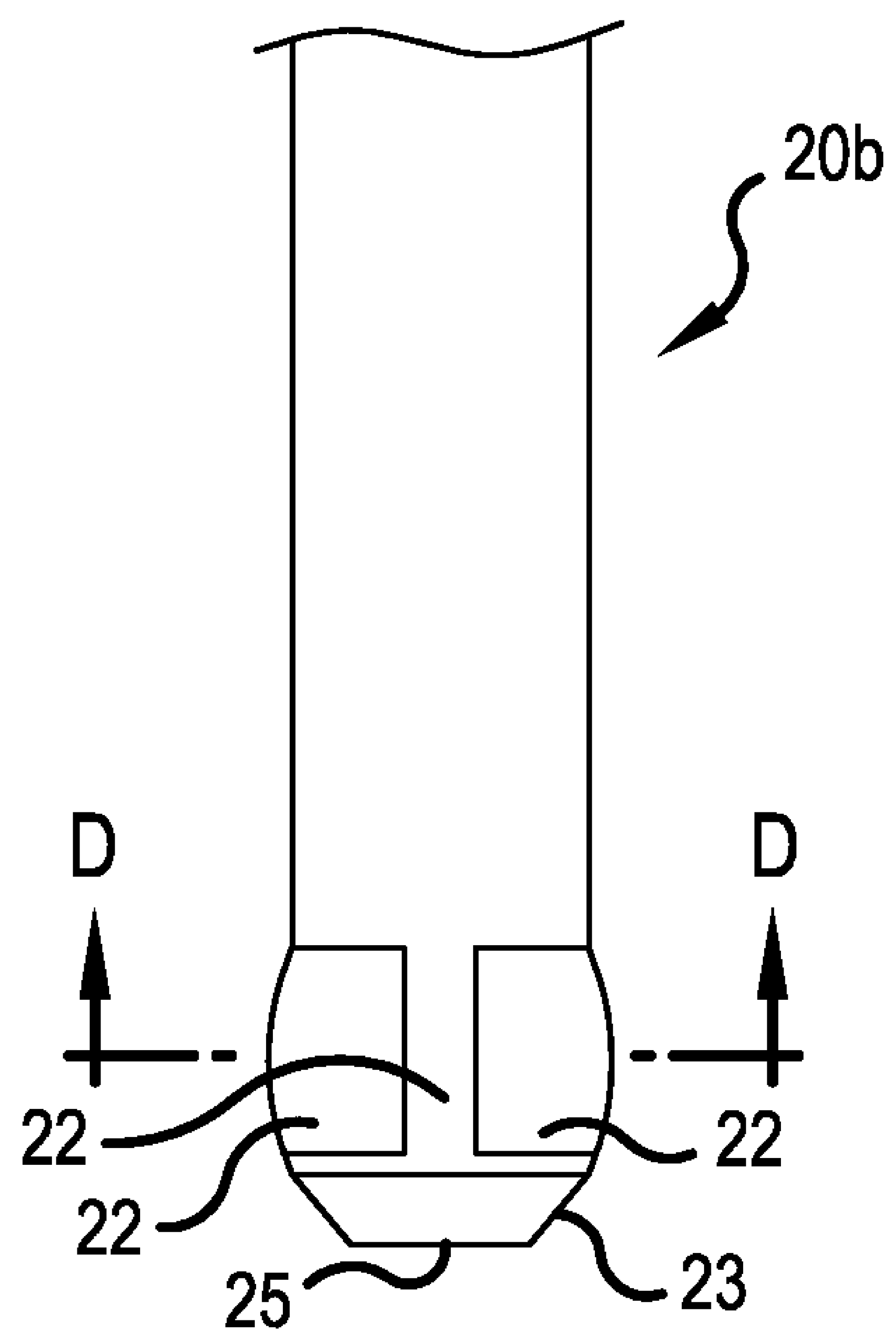

FIG.4(a)

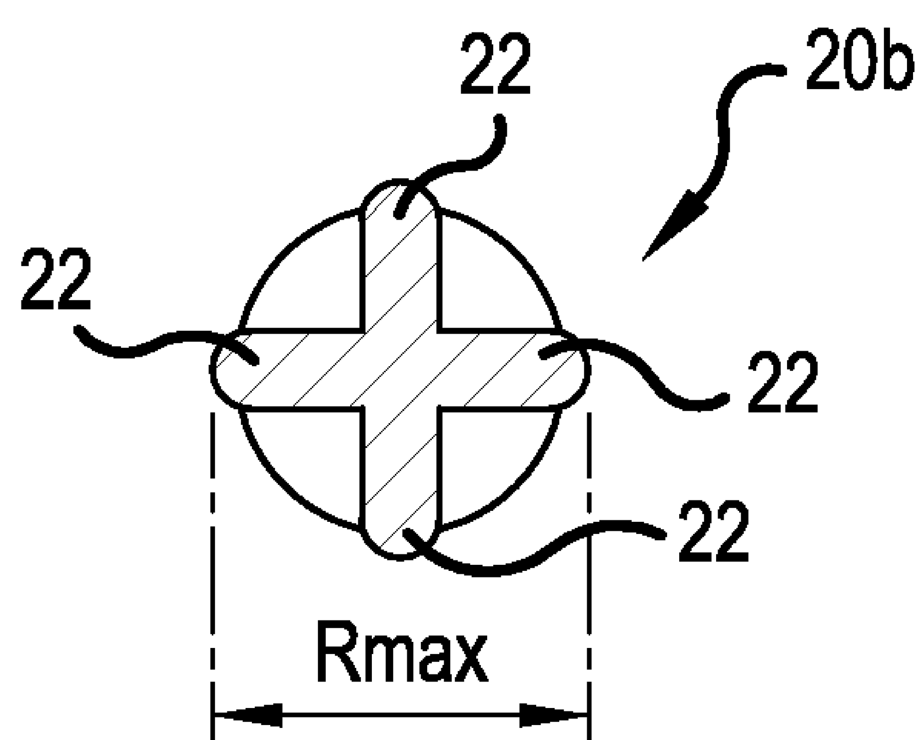

FIG.4(b)

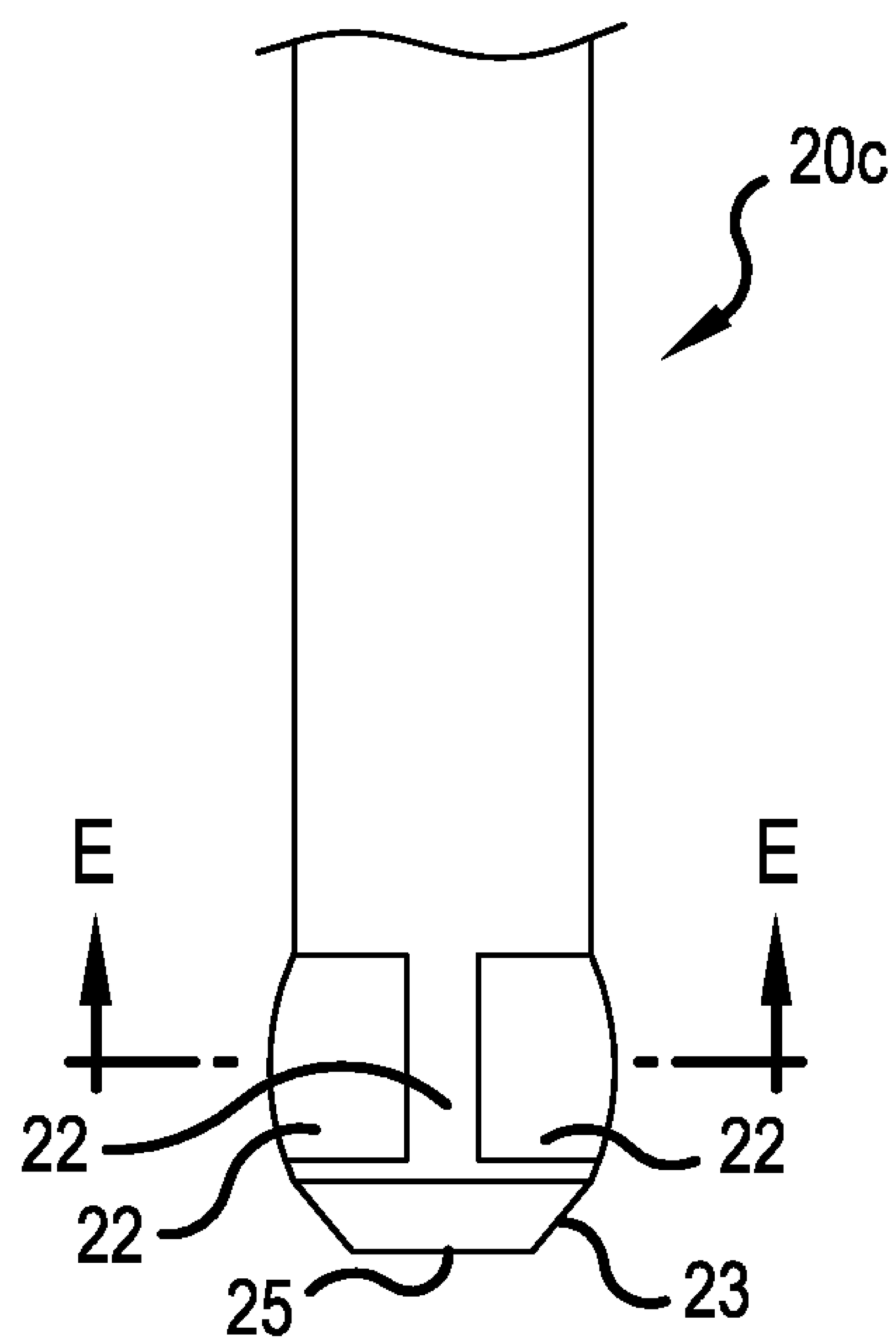

FIG.5(a)

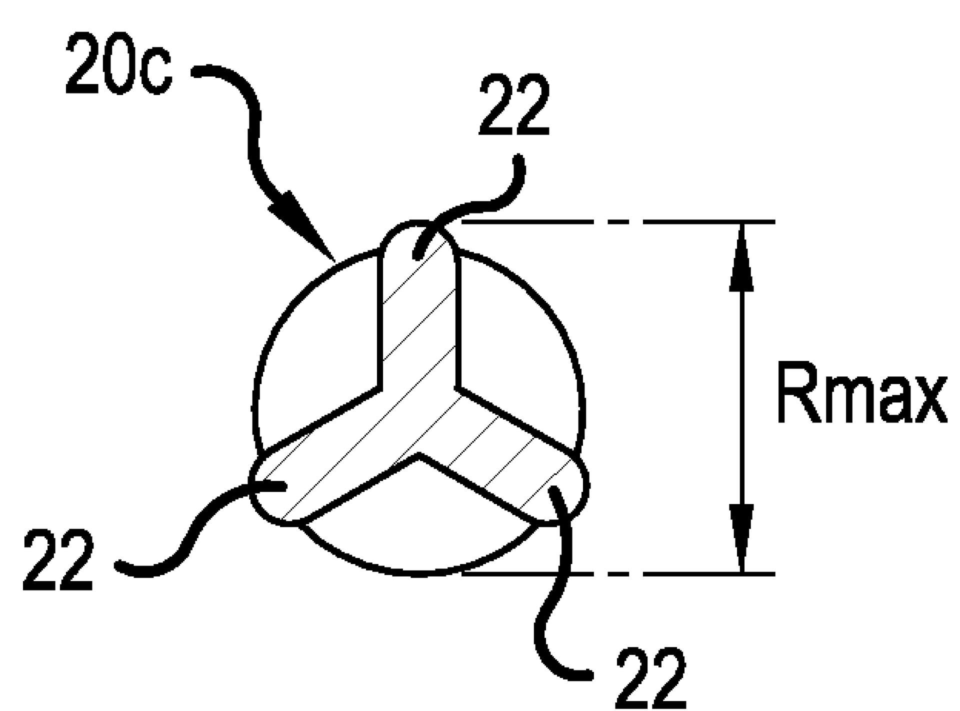

FIG.5(b)

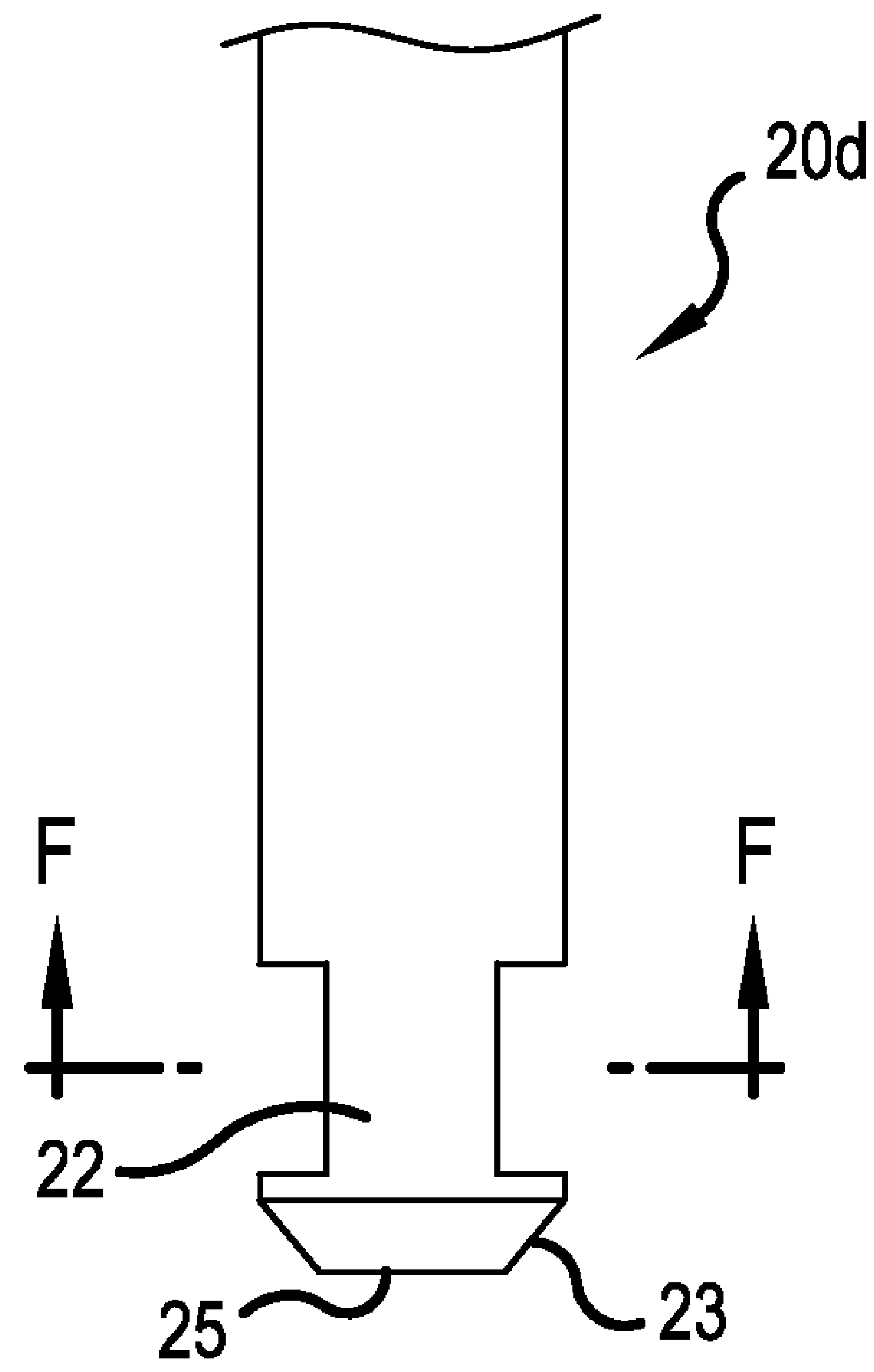

FIG.6(a)

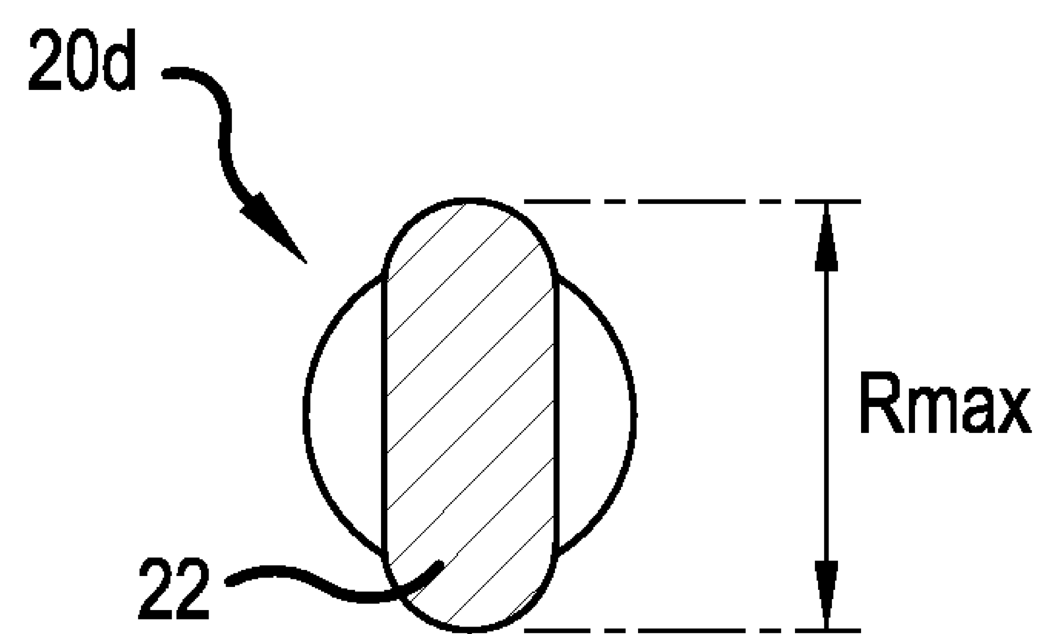

FIG.6(b)

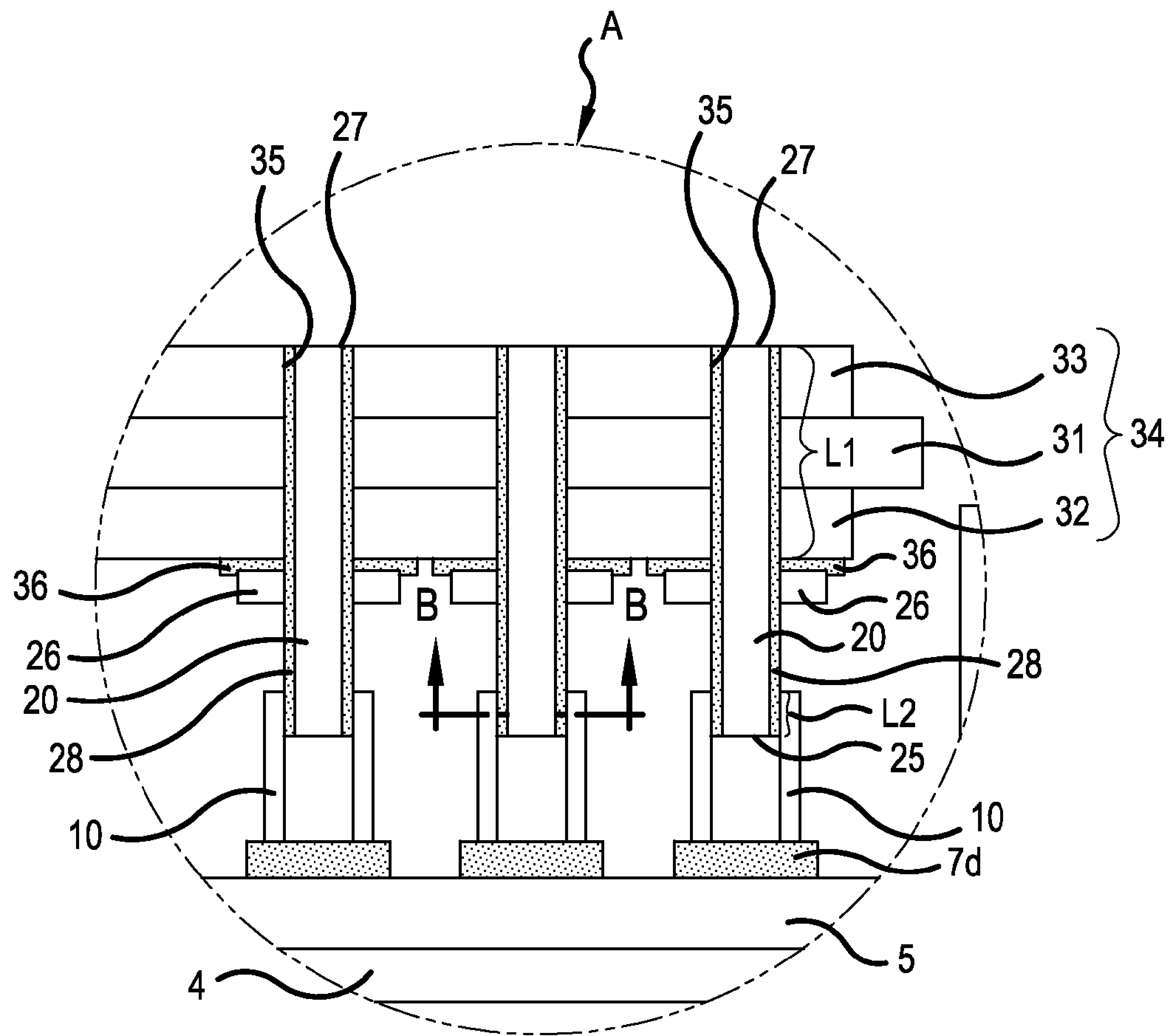

FIG.7

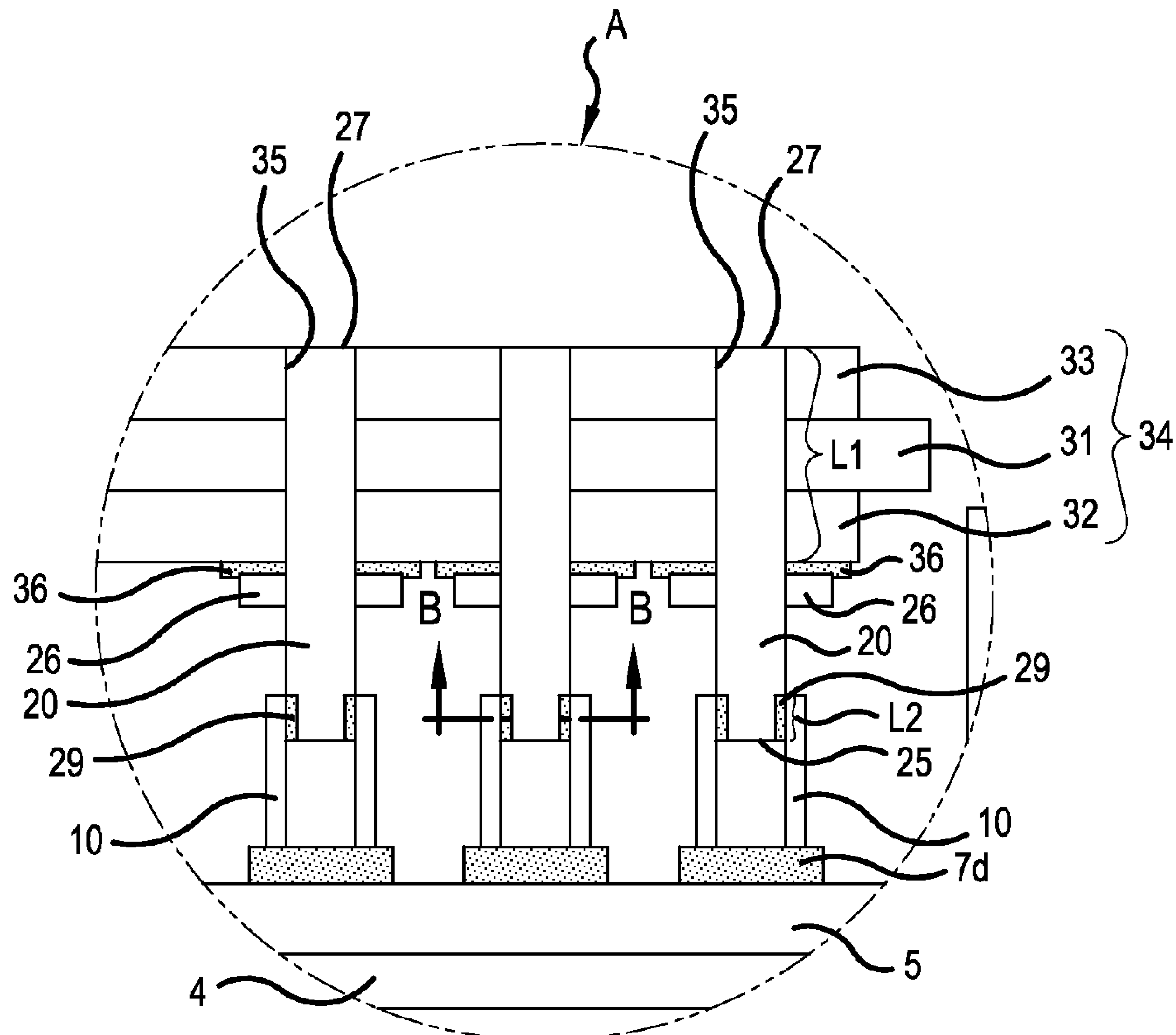

FIG.8

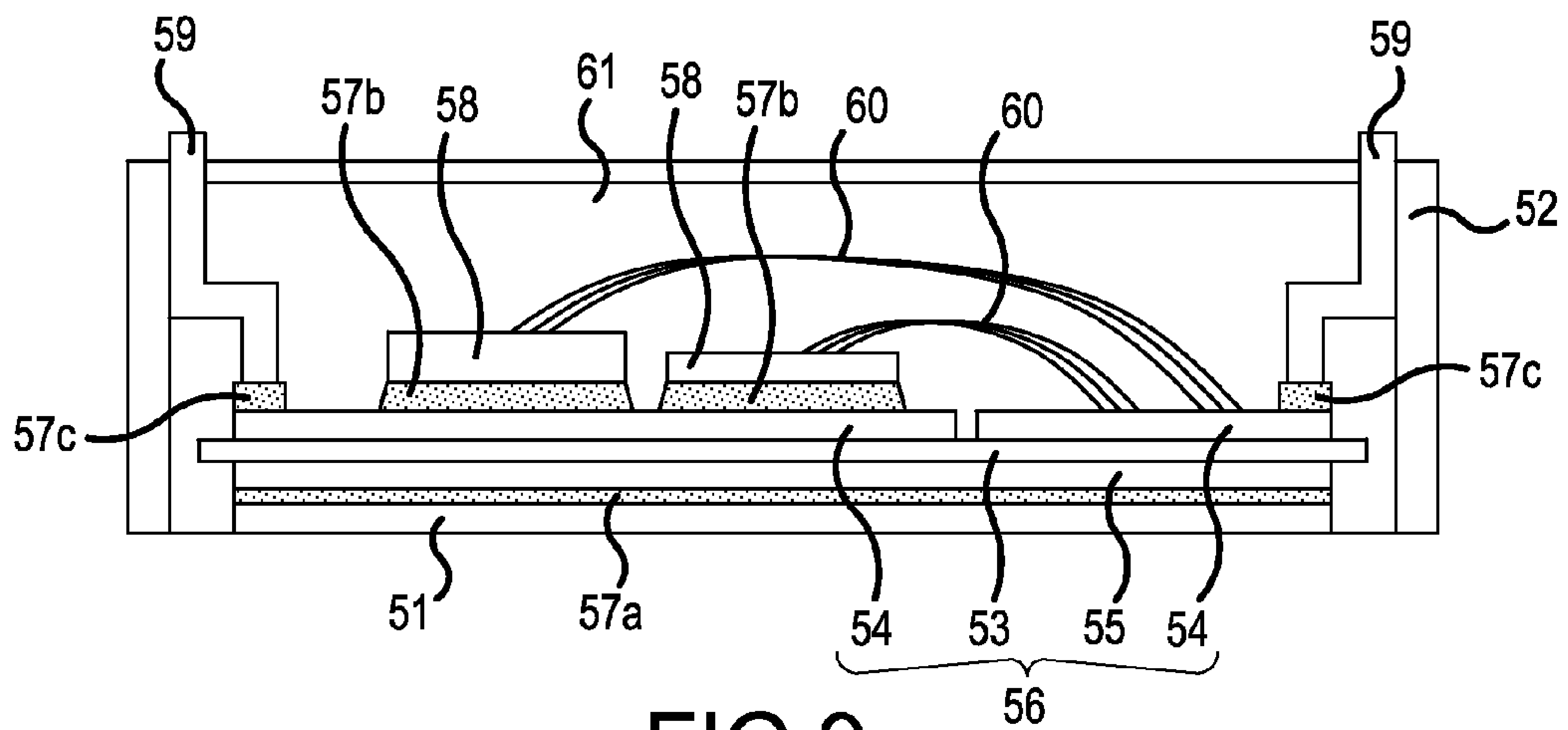

FIG.9

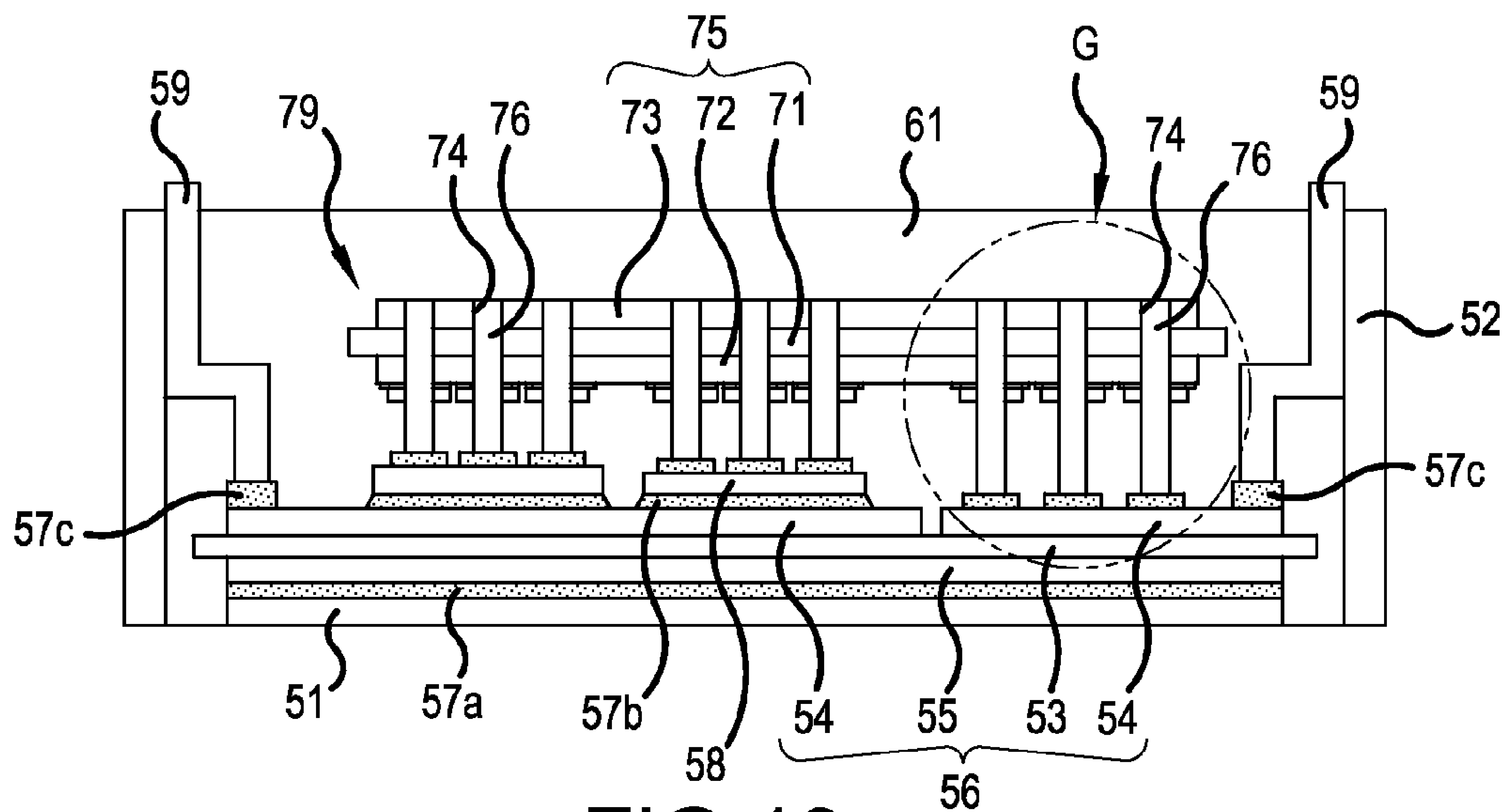

FIG.10

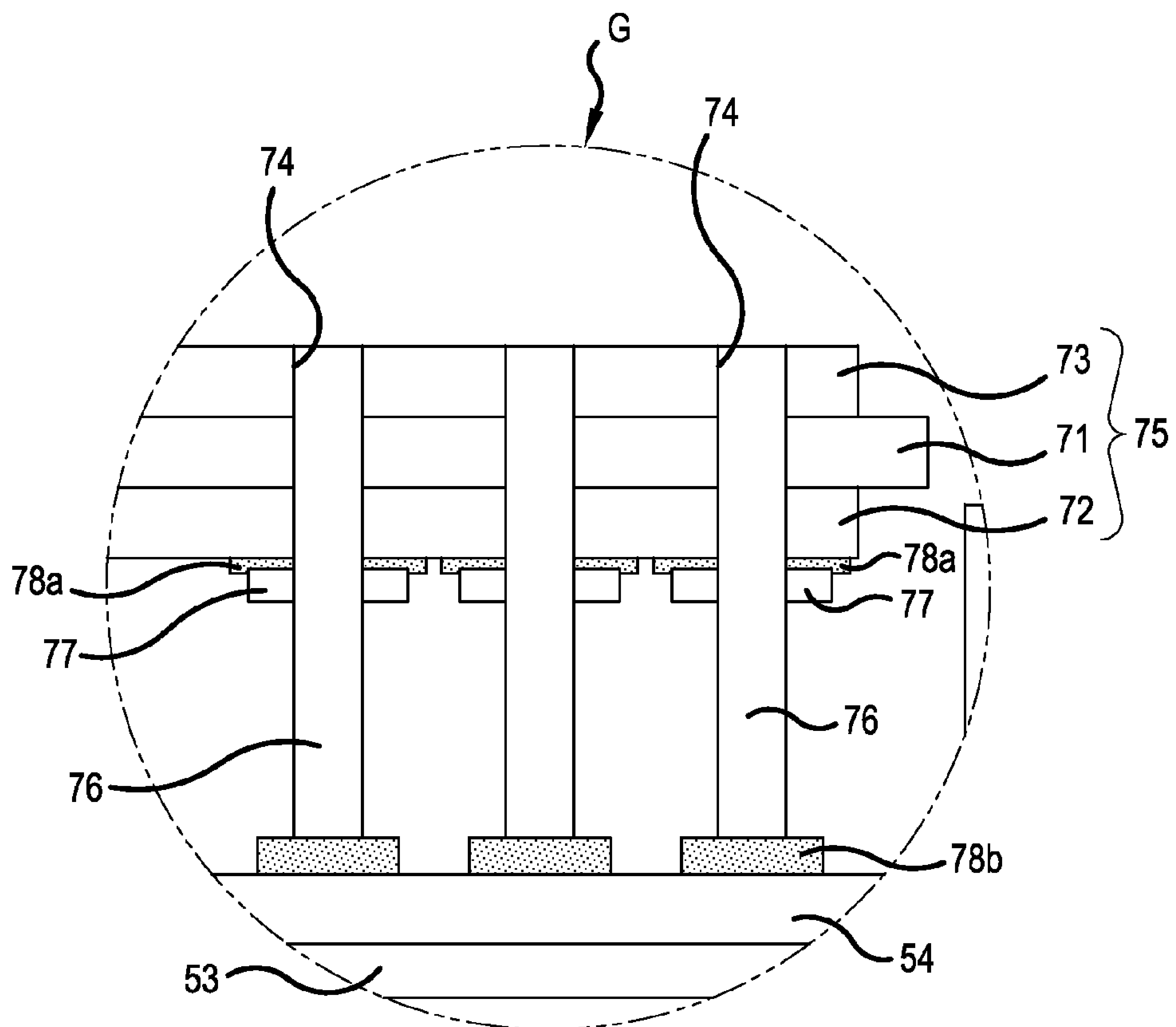

FIG.11

SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING THE SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

A. Field of the Invention

The present invention relates to a semiconductor device and a method for manufacturing the same. Particularly, it relates to a semiconductor device mounted with power semiconductor elements etc. and a method for manufacturing the semiconductor device.

B. Description of the Related Art

An example of a semiconductor device in which semiconductor elements are modularized has a package structure shown in FIG. **9**. In the semiconductor device shown in FIG. **9**, cooling plate **51** is arranged in a bottom portion of resin casing **52**. Insulating wiring board **56** is arranged on cooling plate **51**. Insulating wiring board **56** is configured in such a manner that metal layers **54** and **55** are bonded to opposite surfaces of insulating substrate **53**. Metal layer **55** of insulating wiring board **56** and cooling plate **51** are bonded to each other through solder layer **57***a*. Semiconductor elements **58** are arranged on insulating wiring board **56**. Metal layer **54** of insulating wiring board **56** and semiconductor elements **58** are bonded to each other through solder layer **57***b*. In addition, external terminals **59** are arranged on insulating wiring board **56**. Metal layer **54** of insulating wiring board **56** and external terminals **59** are bonded to each other through solder layer **57***c*. Semiconductor elements **58** are electrically connected to external terminals **59** respectively by bonding wires **60**. The inside of resin casing **52** is filled and sealed with sealing resin **61**.

High heat dissipation is required particularly in the case of semiconductor elements which generate significant heat, like power semiconductor elements such as IGBTs (Insulated Gate Bipolar Transistor) etc. However, in such a semiconductor device according to the background art, bonding wires **60**, for example, consisting of thin aluminum wires each having a wire diameter of about 300 μm to 400 μm are only connected to the upper surface sides of semiconductor elements **58**. Moreover, since heat is generated in accordance with electricity passing through bonding wires **60**, it is almost impossible to obtain any heat dissipation effect from the upper surface sides of semiconductor elements **58**.

A method for improving wiring current density, fusing current resistance, bonding reliability, heat dissipation, etc. has been described in PTL 1 and PTL 2. In PTL 1 and PTL 2, an implant board and semiconductor elements of a semiconductor mounting board are bonded to each other through implant pins in place of the wire bonding wiring structure.

A semiconductor device disclosed in PTL 1 will be described with reference to FIGS. **10** and **11**. Incidentally, portions substantially the same as those in the semiconductor device shown in FIG. **9** are referred to by corresponding numerals, so that description thereof will be omitted.

In the semiconductor device shown in FIG. **10**, semiconductor elements **58** are arranged on insulating wiring board **56**. Metal layer **54** of insulating wiring board **56** and semiconductor elements **58** are bonded to each other through solder layer **57***b*.

Implant board **79** is arranged above semiconductor elements **58**. Implant board **79** and semiconductor elements **58** are electrically connected to each other through implant pins **76** of implant board **79**.

Implant board **79** includes insulating wiring board **75**, and implant pins **76** press-fitted into via holes **74**. Insulating wiring board **75** is configured in such a manner that metal layers **72** and **73** forming a printed wiring are bonded to opposite surfaces of insulating substrate **71**. Via holes **74** are formed to penetrate insulating substrate **71**, metal layer **72** and metal layer **73** of insulating wiring board **75**. Referring now to FIG. **11**, collar portion **77** is provided in each implant pin **76**. A constant quantity between one end of the implant pin and collar portion **77** is press-fitted into via hole **74**. Collar portion **77** and insulating wiring board **75** are bonded to each other through bonding material **78***a*. Moreover, the other end of implant pin **76** is bonded to insulating wiring board **56** or semiconductor element **58** through bonding material **78***b*

PTL 1: JP-A-2011-82303
PTL 2: WO 2011/083737

SUMMARY OF THE INVENTION

However, when the component configuration in the semiconductor device shown in FIG. **10** is changed for each kind of product so that the heights of components including the semiconductor elements etc. are changed, it is necessary to adjust the length of each implant pin in accordance with the distance between the semiconductor element and the implant board in each bonding place. Therefore, it is necessary to prepare a number of implant boards in accordance with the number of the kinds of products, so that time and labor are required for inventory management of these components. In addition, a plurality of kinds of implant boards must be prepared in accordance with the kinds of products, so that the component cost increases.

Therefore, the present invention provides a semiconductor device in which an implant board and semiconductor elements of a semiconductor mounting board are bonded and electrically connected through implant pins and which can be manufactured with high productivity, and provides a method for manufacturing the semiconductor device.

The semiconductor device according to the invention is characterized in that the implant pins are bonded to a semiconductor element and/or a circuit pattern of the semiconductor mounting board through cylindrical terminals press-fitted onto the other ends of the implant pins, and the depth with which each of the implant pins is press-fitted into corresponding one of the cylindrical terminals can be adjusted so that total length of the implant pin and the cylindrical terminal which are press-fitted to each other can match up with a distance between the semiconductor element and/or the circuit pattern on the semiconductor mounting board and the implant board.

In the semiconductor device according to the invention, the implant pins are bonded to the semiconductor element and/or the circuit pattern of the semiconductor mounting board through the cylindrical terminals press-fitted onto the other ends of the implant pins. Therefore, the depth with which each of the implant pins is press-fitted into corresponding one of the cylindrical terminals can be adjusted so that the total length of the implant pin and the cylindrical terminal which are press-fitted to each other can match up with the distance between the semiconductor element and/or the circuit pattern on the semiconductor mounting board and the implant board. Accordingly, even when the distance between the semiconductor element and/or the circuit pattern on the semiconductor mounting board and the implant board differs from one bonding portion to another, it is not necessary to prepare implant pins whose lengths match up with bonding portions individually. That is, it is not necessary to change the kind of the implant board in accordance with each kind of product, but the implant board can be used in common among a plu-

rality of products. Therefore, inventory management of the components can be easy and the component cost can be suppressed. Thus, the productivity is excellent.

In the semiconductor device according to the invention, a plating layer may be provided in a surface of a press-fitting portion of each of the implant pins into corresponding one of the cylindrical terminals and/or an inner circumferential surface of the cylindrical terminal. Preferably, the implant pin press-fitted into the cylindrical terminal is heated to melt the plating layer so that a contact portion between the implant pin and the cylindrical terminal can be bonded to each other by the plating layer.

In the semiconductor device according to the invention, a sinter material may be applied to a surface of a press-fitting portion of each of the implant pins into corresponding one of the cylindrical terminals and/or an inner circumferential surface of the cylindrical terminal. Preferably, the implant pin press-fitted into the cylindrical terminal is heated to sinter the sinter material so that a contact portion between the implant pin and the cylindrical terminal can be bonded to each other.

According to the aforementioned aspects, the bonding strength between each of the implant pins and corresponding one of the cylindrical terminals is so high that the bonding reliability is excellent.

In the semiconductor device according to the invention, preferably, each of the implant pins is in contact with at least 40% of an inner circumference of corresponding one of the cylindrical terminals in a section perpendicular to the implant pin in a contact portion between the implant pin and an inner circumferential surface of the cylindrical terminal. According to this aspect, the conductivity is excellent. Furthermore, the bonding strength between the implant pin and the cylindrical terminal is high, and the bonding reliability is excellent.

In the semiconductor device according to the invention, preferably, a protruding portion which protrudes over an outer circumference of each of the implant pins is provided in a press-fitting portion of the implant pin into corresponding one of the cylindrical terminals by drawing, so that the protruding portion can come into contact with an inner circumferential surface of the cylinder terminal. In this aspect, preferably, a value obtained by subtracting an inner diameter of each of the cylindrical terminals from a largest diameter of a press-fitting portion of corresponding one of the implant pins which has not yet been press-fitted is in the range of from 0 to 0.25 mm.

In the semiconductor device according to the invention, preferably, a straight columnar portion which is not subjected to drawing is provided in a press-fitting portion of each of the implant pins so that at least a part of the columnar portion can come into contact with an inner circumferential surface of corresponding one of the cylindrical terminals. In this aspect, preferably, a value obtained by subtracting an inner diameter of each of the cylindrical terminals from a largest diameter of a press-fitting portion of corresponding one of the implant pins which has not yet been press-fitted is in the range of from 0 to 0.15 mm.

According to the aforementioned aspects, the bonding strength between each of the implant pins and corresponding one of the cylindrical terminals is high and the bonding reliability is excellent.

In the semiconductor device according to the invention, preferably, each of the implant pins has a tapered end on the cylindrical terminal side so that the implant pin has a diameter which decreases toward the end. According to this aspect, an operation of press-fitting the implant pin into the cylindrical terminal becomes easy.

In the semiconductor device according to the invention, preferably, an inner circumference of each of the cylindrical terminals is formed into a shape which matches up with a press-fitting portion of corresponding one of the implant pins. In this aspect, the contact area of the implant pin with the inner circumference of the cylindrical terminal can be increased. Thus, the conductivity and the bonding strength are excellent.

In addition, the semiconductor device manufacturing method according to the invention is a method for manufacturing a semiconductor device, including the steps of: preparing a semiconductor mounting board in which a semiconductor element is mounted on an insulating wiring board; preparing an implant board in which via holes for electric connection are provided in an insulating substrate having a printed wiring and one ends of implant pins are press-fitted into the via holes; and bonding the other ends of the implant pins of the implant board to the semiconductor element and/or a circuit pattern of the semiconductor mounting board so as to make electric connection to the semiconductor element of the semiconductor mounting board; characterized in that: each of cylindrical terminals is press-fitted onto the other end of corresponding one of the implant pins and depth with which the cylindrical terminal is press-fitted is adjusted so that length of the implant pin can match up with a distance between the semiconductor element and/or the circuit pattern on the semiconductor mounting board and the implant board and the implant pin can be bonded to the semiconductor element and/or the circuit pattern of the semiconductor mounting board through the cylindrical terminal.

In the semiconductor device manufacturing method according to the invention, a plating layer may be formed in a surface of a press-fitting portion of each of the implant pins into corresponding one of the cylindrical terminals and/or an inner circumferential surface of the cylindrical terminal. The other end of the implant pin of the implant board is made to abut against the semiconductor element and/or the circuit pattern of the semiconductor mounting board through the cylinder terminal and the semiconductor device thus assembled is heated in a reflow furnace in this state. Thus, connection is made between the semiconductor element and the insulating wiring board and connection is made between the cylindrical terminal corresponding to the implant pin and the semiconductor element and/or the circuit pattern of the semiconductor mounting board. In addition thereto, preferably, the plating layer is melted to thereby connect the implant pin and the cylindrical terminal to each other.

In the semiconductor device manufacturing method according to the invention, a sinter material may applied in a surface of a press-fitting portion of each of the implant pins into corresponding one of the cylindrical terminals and/or an inner circumferential surface of the cylindrical terminal. The other end of the implant pin of the implant board abuts against the semiconductor element and/or the circuit pattern of the semiconductor mounting board through the cylinder terminal and the semiconductor device thus assembled is heated in a reflow furnace in this state. Thus, connection is made between the semiconductor element and the insulating wiring board and connection is made between the cylindrical terminal corresponding to the implant pin and the semiconductor element and/or the circuit pattern of the semiconductor mounting board. In addition thereto, preferably, the sinter material is sintered to thereby connect the implant pin and the cylindrical terminal to each other.

According to the invention, the implant board can be used in common among a plurality of products. Accordingly, inventory management of the components can be performed

easily and the component cost can be suppressed so that a semiconductor device in which semiconductor elements are electrically connected by the implant board can be manufactured with high productivity.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing advantages and features of the invention will become apparent upon reference to the following detailed description and the accompanying drawings, of which:

FIG. **1** is a schematic sectional view showing an embodiment of a semiconductor device according to the invention;

FIG. **2** is an enlarged view of a portion A in FIG. **1**;

FIGS. **3**(*a*) and **3**(*b*) are a schematic view of an external terminal which can be used in the semiconductor device, in which **3**(*a*) is a side view and **3**(*b*) is a sectional view taken along the line C-C in **3**(*a*);

FIGS. **4**(*a*) and **4**(*b*) are a schematic view of an external terminal which can be used in the semiconductor device, in which **4**(*a*) is a side view and **4**(*b*) is a sectional view taken along the line D-D in **4**(*a*);

FIGS. **5**(*a*) and **5**(*b*) are a schematic view of an external terminal which can be used in the semiconductor device, in which **5**(*a*) is a side view and **5**(*b*) is a sectional view taken along the line E-E in **5**(*a*);

FIGS. **6**(*a*) and **6**(*b*) are a schematic view of an external terminal which can be used in the semiconductor device, in which **6**(*a*) is a side view and **6**(*b*) is a sectional view taken along the line F-F in **6**(*a*);

FIG. **7** is an important part enlarged sectional view showing another embodiment of the semiconductor device according to the invention;

FIG. **8** is an important part enlarged sectional view showing further another embodiment of the semiconductor device according to the invention;

FIG. **9** is a schematic sectional view showing an example of a semiconductor device according to the background art;

FIG. **10** is a schematic sectional view showing another example of the semiconductor device according to the background art;

FIG. **11** is an enlarged view of a portion G in FIG. **10**;

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

A semiconductor device according to the invention will be described with reference to the drawings. An embodiment of the semiconductor device according to the invention is shown in FIG. **1**.

In the semiconductor device, cooling plate **1** is arranged in a bottom portion of resin casing **2**. Cooling plate **1** is made of a material having high heat dissipation. For example, copper, aluminum, a copper alloy, an aluminum alloy, etc. may be used as the material of cooling plate **1**.

Insulating wiring board **3** is arranged on cooling plate **1**. Insulating wiring board **3** is formed in such a manner that metal layers **5** and **6** are bonded to opposite surfaces of insulating substrate **4**. A predetermined circuit pattern is formed on insulating substrate **4** by metal layer **5**. Metal layer **6** of insulating wiring board **3** and cooling plate **1** are bonded through a solder or sinter material layer **7***a*.

There is no particular limitation on insulating wiring board **3**. For example, a direct bonding copper board in which a copper plate is bonded directly on a ceramic substrate, an active metal brazed copper board in which ceramics and a copper plate are bonded through a brazing material, or the like, may be used as insulating wiring board **3**.

External terminals **9** are bonded to predetermined places of metal layer **5** forming the circuit pattern of insulating wiring board **3**, through a solder or sinter material layer **7***b*. In addition, a plurality of semiconductor elements **8***a* and **8***b* are bonded to the same metal layer **5** through a solder or sinter material layer **7***c*. Each of semiconductor elements **8***a* and **8***b* varies according to use purposes. For example, a power semiconductor element such as an IGBT, a rectifier element such as an FWD, etc. may be used as semiconductor element **8***a*, **8***b*.

Implant board **30** is disposed above semiconductor element **8**. Implant board **30** includes insulating wiring board **34**, and implant pins **20** press-fitted into via holes **35**. Insulating wiring board **34** is configured in such a manner that metal layers **32** and **33** forming a printed wiring are bonded to opposite surfaces of insulating substrate **31**. Each of via holes **35** is formed to penetrate metal layer **32**, insulating substrate **31** and metal layer **33** of insulating wiring board **34**. A metal layer (not-shown) connected conductively to metal layer **32** and/or metal layer **33** is formed in an inner surface of each of via holes **35**. The metal layer in the inner surface is connected conductively to implant pin **20**.

Lower ends of some of implant pins **20** of implant board **30** are press-fitted into cylindrical terminals **10**. In the embodiment, implant pins **20** which do not have cylindrical terminals **10** are connected to semiconductor element **8***a* through a solder or sinter material layer **7***e*. Moreover, cylindrical terminals **10** in implant pins **20** having cylindrical terminals **10** are connected to semiconductor element **8***b* and metal layer **5** through a solder or sinter material layer **7***d*.

Referring now to FIG. **2**, collar portion **26** is provided in each of implant pins **20**. A constant quantity L**1** between end **27** of each implant pin and collar portion **26** is press-fitted into pin hole **35**. Each of collar portions **26** and insulating wiring board **34** are bonded through bonding material **36**.

Press-fitting depth L**2** of each of implant pins **20** into cylindrical terminals **10** is adjusted for each cylindrical terminal so as to match up with the distance between semiconductor element **8***b* and implant board **30** and the distance between metal layer **5** and implant board **30**.

That is, an implant board provided with implant pins having different lengths in accordance with the distance between semiconductor element **8** and implant board **30** and the distance between metal layer **5** and implant board **30** is not used in the invention. According to the invention, the press-fitting depth of each implant pin **20** into a corresponding cylindrical terminal **10** is changed in accordance with each of the distances. Thus, implant board **30** is bonded to semiconductor element **8** or metal layer **5** to make electric connection for each of the semiconductor elements. Therefore, it is not necessary to change the implant board in accordance with each kind of product so that the implant board can be used in common among a plurality of products.

Incidentally, when the distance between implant board **30** and semiconductor element **8** or metal layer **5** matches up with the length of each implant pin **20** extending from implant board **30**, implant pin **20** may be bonded to semiconductor element **8** or metal layer **5** not through cylindrical terminal **10**. In the embodiment, the distance between implant board **30** and semiconductor element **8***a* matches up with the length of each implant pin **20** extended from implant board **30**, so that implant pin **20** is bonded directly to semiconductor element **8***a* through a solder or sinter material layer **7***e*.

In the semiconductor device according to the invention, it is preferable that each implant pin **20** is in contact with 40% or more of the inner circumference of cylindrical terminal **10** in a section taken along the line B-B in FIG. **2**. The section

taken along the line B-B in FIG. **2** is a section in a direction perpendicular to implant pin **20**, in a contact portion between implant pin **20** and the inner circumference of cylindrical terminal **10**. When the contact area of implant pin **20** with cylindrical terminal **10** is smaller than 40%, bonding strength or conductivity may be insufficient. When the contact area is not smaller than 40%, sufficient bond strength and conductivity can be obtained.

In the semiconductor device according to the invention, there is no particular limitation on the shape of implant pin **20**. An implant pin having any shape such as a cylindrical shape or a prismatic shape can be used as implant pin **20**. For example, any of the shapes shown in FIGS. **3** to **6** may be preferably used as the shape of the press-fitting portion of implant pin **20** into cylindrical terminal **10**.

Implant pin **20***a* shown in FIG. **3** is provided with a press-fitting portion consisting of straight columnar portion **21** which is not subjected to drawing, and reduced diameter portion **23** whose diameter is reduced like a taper from the press-fitting portion toward end **25**. When implant pin **20***a* is press-fitted into cylindrical terminal **10**, columnar portion **21** comes into contact with the inner circumferential surface of cylindrical terminal **10**, so that columnar portion **21** and cylindrical terminal **10** are bonded to each other. Moreover, since end **25** has a reduced diameter like a taper, the center position can be adjusted easily when implant pin **20***a* is press-fitted into cylindrical terminal **10**. Thus, the press-fitting is performed easily.

The largest outer diameter R_{max} of the press-fitting portion of implant pin **20** which has not yet been press-fitted is set so that a difference (R_{max}−R) between the largest outer diameter R_{max} and an inner diameter R of cylindrical terminal **10** is preferably in the range of from 0 to 0.15 mm. In addition, the difference (R_{max}−R) between the largest outer diameter R_{max} and the inner diameter R of cylindrical terminal **10** is more preferably in the range of from 0.05 mm to 0.15 mm, especially preferably in the range of from 0.05 mm to 0.10 mm. When the largest outer diameter R_{max} is set such that the difference is within the aforementioned range, implant pin **20***a* can be press-fitted into cylindrical terminal **10** without causing any damage in implant pin **20***a*, any damage in cylindrical terminal **10**, etc. so that implant pin **20***a* and cylindrical terminal **10** can be bonded to each other firmly.

Each of implant pins **20***b* to **20***d* shown in FIGS. **4** to **6** is provided with a press-fitting portion having protruding portion **22** protruding over the outer circumference due to drawing, and reduced diameter portion **23** whose diameter is reduced like a taper from the press-fitting portion toward end **25**. In implant pin **20***b* shown in FIG. **4**, protruding portion **22** is formed into a cross shape in section. In implant pin **20***c* shown in FIG. **5**, protruding portion **22** is formed into a Y-shape in section (a shape having three protruding parts protruding radially at equal angles). In implant pin **20***d* shown in FIG. **6**, protruding portion **22** is formed into a flat plate shape. When the implant pin is press-fitted into cylindrical terminal **10**, protruding portion **22** comes into contact with the inner circumferential surface of cylindrical terminal **10** so that protruding portion **22** and cylindrical terminal **10** are bonded to each other. Moreover, since end **25** is reduced in diameter like a taper, the center position can be adjusted easily when implant pin **20** is press-fitted into cylindrical terminal **10**. Thus, the press-fitting can be performed easily. Incidentally, the shape of the protruding portion formed by drawing is not limited to any of the shapes shown in FIGS. **4** to **6**.

The largest outer diameter R_{max} of the press-fitting portion in each of implant pins **20***b* to **20***d* which has not yet been press-fitted is set so that a difference (R_{max}−R) between the largest outer diameter R_{max} and the inner diameter R of cylindrical terminal **10** is preferably in the range of from 0 to 0.25 mm. Moreover, the difference (R_{max}−R) between the largest outer diameter R_{max} and the inner diameter R of cylindrical terminal **10** is more preferably in the range of from 0.05 mm to 0.25 mm, particularly preferably in the range of from 0.10 mm to 0.20 mm. When the largest outer diameter R_{max} is set so that the difference is within the aforementioned range, the implant pin can be press-fitted into cylindrical terminal **10** without causing any damage in the implant pin, any damage in cylindrical terminal **10**, etc. so that the implant pin and cylindrical terminal **10** can be bonded to each other firmly.

The inner circumference of cylindrical terminal **10** is preferably shaped like a hole which matches up with the press-fitting portion of implant pin **20**. Since the inner circumference of cylindrical terminal **10** is formed into a shape which matches up with the press-fitting portion of implant pin **20**, the contact area of implant pin **20** with the inner circumference of cylindrical terminal **10** can be made large. In addition, the ends of protruding portions **22** engage with the inner circumferences of cylindrical terminals **10** respectively so as to prevent rotation.

The inside of resin casing **2** in the semiconductor device according to the invention is filled and sealed with sealing resin **15** such as a gel or an epoxy resin.

Next, an embodiment of a semiconductor device manufacturing method according to the invention will be described as a method for manufacturing the aforementioned semiconductor device.

First, a method for manufacturing implant board **30** will be described. Implant board **30** is manufactured as follows. Via holes **35** for electric connection are formed in predetermined positions of insulating wiring board **34** so as to penetrate metal layer **32**, insulating substrate **31** and metal layer **33**. After ends **27** of implant pins **20** are press-fitted into via holes **35**, collar portions **26** of implant pins **20** and insulating wiring board **34** are bonded by bonding material **36**.

The method for manufacturing the semiconductor device will be described below.

Insulating wiring board **3** is disposed on cooling plate **1** so that metal layer **6** side of insulating wiring board **3** can come into contact with cooling plate **1** through a solder or sinter material layer **7***a*. Moreover, semiconductor elements **8***a* and **8***b* are disposed on a predetermined circuit pattern of metal layer **5** of insulating wiring board **3** through a solder or sinter material layer **7***c*.

Next, implant pins **20** extending from implant board **30** are press-fitted into cylindrical terminals **10**. The press-fitting depth of each of implant pins **20** is adjusted so that the length of implant pin **20** can match up with the distance between semiconductor element **8***b* and implant board **30** or the distance between metal layer **5** and implant board **30**.

Implant board **30** is disposed above insulating wiring board **3**. Cylindrical terminals **10** are disposed in predetermined positions of semiconductor element **8***b* and metal layer **5** through a solder or sinter material layer **7***d*. In addition thereto, implant pins **20** extending from implant board **30** are disposed on semiconductor element **8***a* through a solder or sinter material layer **7***e*.

The semiconductor device is introduced into a reflow furnace in this state so that the solder or sinter material layers **7***a*, **7***c*, **7***d* and **7***e* are melted or sintered. Thus, cooling plate **1** and metal layer **6** of insulating wiring board **3** are bonded to each other. At the same time, bonding between semiconductor elements **8***a* and **8***b* and metal layer **5** of insulating wiring board **3**, bonding between cylindrical terminals **10** and metal

layer **5** of insulating wiring board **3**, bonding between cylindrical terminals **10** and semiconductor element **8*b*** and bonding between implant pins **20** and semiconductor element **8*a*** are performed.

The heating temperature in the reflow time is preferably not higher than 350° C., more preferably in the range of from 250° C. to 330° C. When the heating temperature is higher than 350° C., there is a fear that the semiconductor elements etc. may be thermally damaged.

Next, external terminals **9** are disposed in predetermined positions of metal layer **5** through a solder or sinter material layer **7*b***. The solder or sinter material layer **7*b*** is melted or sintered to bond external terminals **9** and metal layer **5** to each other. Cooling plate **1** is surrounded by resin casing **2**. The inside enclosed by resin casing **2** is filled with sealing resin **15**. The sealing resin is hardened. In this manner, the semiconductor device according to the invention is manufactured.

Another embodiment of the semiconductor device according to the invention is shown in FIG. **7**. In the semiconductor device, plating layer **28** is provided in the surface of the press-fitting portion of each implant pin **20** into cylindrical terminal **10**. When plating layer **28** is melted, the press-fitting portion of implant pin **20** and the inner circumferential surface of cylindrical terminal **10** are bonded to each other. Incidentally, in the embodiment, the plating layer is formed in the surface of the press-fitting portion of implant pin **20**. Alternatively, the plating layer may be formed in the inner circumferential surface of cylindrical terminal **10** or may be formed in both the surface of the press-fitting portion of implant pin **20** and the inner circumferential surface of cylindrical terminal **10**.

The thickness of plating layer **28** is preferably not larger than 5 μm prior to press-fitting. Plating layer **28** may be a single layer or may be a laminate of a plurality of plating layers. A layer or a laminate in which at least the outermost layer can be melted at a temperature not higher than 350° C. is preferably used. Sn plating, SnAg-based solder plating, SnBi-based solder plating, SnSb-based solder plating, SnCu-based solder plating, SnIn-based solder plating, etc. may be used as the plating material whose melting temperature is not higher than 350° C. When the melting temperature is not higher than 350° C., the plating material can be melted in the reflow process for soldering the semiconductor elements etc.

Next, another embodiment of a semiconductor device manufacturing method according to the invention will be described as a method for manufacturing the aforementioned semiconductor device. In the embodiment, implant pins **20** extending from implant board **30** are press-fitted into cylindrical terminals **10** and the press-fitting depth of each of implant pins **20** is adjusted, in the same manner as in the aforementioned embodiment. In this manner, the length of each of implant pins **20** matches up with the distance between semiconductor element **8*b*** and implant board **30** or the distance between metal layer **5** and implant board **30**. Cylindrical terminals **10** are disposed in predetermined positions of semiconductor element **8*b*** and metal layer **5** through the solder or sinter material layer **7*d***. Moreover, implant pins **20** extending from implant board **30** are disposed on semiconductor element **8*a*** through the solder or sinter material layer **7*e***.

The semiconductor device is introduced into a reflow furnace in this state so that the solder or sinter material layers **7*a***, **7*c***, **7*d*** and **7*e*** and plating layer **28** are melted or sintered. Thus, through the solder or sinter material layers **7*a***, **7*c***, **7*d*** and **7*e***, cooling plate **1** and metal layer **6** of insulating wiring board **3** are bonded to each other. At the same time, bonding between semiconductor elements **8*a*** and **8*b*** and metal layer **5** of insulating wiring board **3**, bonding between cylindrical terminals **10** and metal layer **5** of insulating wiring board **3**, bonding between cylindrical terminals **10** and semiconductor element **8*b***, and bonding between implant pins **20** and semiconductor element **8*a*** are performed. In addition, implant pins **20** and cylindrical terminals **10** are bonded to each other respectively through plating layer **28**.

The heating temperature in the reflow time is preferably not higher than 350° C., more preferably in the range of from 250° C. to 330° C. When the heating temperature is higher than 350° C., there is a fear that the semiconductor elements etc. may be thermally damaged.

External terminals **9** are disposed in predetermined positions of metal layer **5** through the solder or sinter material layer **7*b***. When the solder or sinter material layer **7*b*** is melted or sintered, metal layer **5** and external terminals **9** are bonded to each other. Further, cooling plate **1** is surrounded by resin casing **2**. The internal portion enclosed by resin casing **2** is filled with sealing resin **15**. The sealing resin is hardened. In this manner, the semiconductor device is manufactured.

Further another embodiment of the semiconductor device according to the invention is shown in FIG. **8**. In the semiconductor device, implant pins **20** are press-fitted into cylindrical terminals **10**. Sinter material **29** is applied to the surfaces of the press-fitting portions of implant pins **20** into cylindrical terminals **10** and/or the inner circumferential surfaces of cylindrical terminals **10**. When the sinter material is sintered, the press-fitting portions of implant pins **20** and the inner circumferential surfaces of cylindrical terminals **10** are bonded to each other.

A sinter material which can be sintered at a temperature not higher than 350° C. is preferably used as sinter material **29**. For example, an Ag-based sinter material, a Cu-based sinter material, etc. may be used as sinter material **29**. When the sintering temperature is not higher than 350° C., the sinter material can be sintered in the reflow process for soldering the semiconductor elements etc.

Next, another embodiment of a semiconductor device manufacturing method according to the invention will be described as a method for manufacturing the aforementioned semiconductor device.

In the embodiment, sinter material **29** is applied to the inner circumferential surfaces of cylindrical terminals **10** and/or the press-fitting portions of implant pins **20** into cylindrical terminals **10**. Then, implant pins **20** extending from implant board **30** are press-fitted into cylindrical terminals **10** and the press-fitting depths of implant pins **20** are adjusted. In this manner, the lengths of implant pins **20** match up with the distance between semiconductor element **8*b*** and implant board **30** and the distance between metal layer **5** and implant board **30**. Cylindrical terminals **10** are disposed in predetermined positions of semiconductor element **8*b*** and metal layer through the solder or sinter material layer **7*d***. Moreover, implant pins **20** extending from implant board **30** are disposed on semiconductor element **8*a*** through the solder or sinter material layer **7*e***.

The semiconductor device is introduced into a reflow furnace in this state so that the solder or sinter material layers **7*a***, **7*c***, **7*d*** and **7*e*** and sinter material **29** are melted or sintered. Thus, through the solder or sinter material layers **7*a***, **7*c***, **7*d*** and **7*e***, cooling plate **1** and metal layer **6** of insulating wiring board **3** are bonded to each other. At the same time, bonding between the semiconductor elements **8*a*** and **8*b*** and metal layer **5** of insulating wiring board **3**, bonding between cylindrical terminals **10** and metal layer **5** of insulating wiring board **3**, bonding between cylindrical terminals **10** and semiconductor element **8*b***, and bonding between implant pins **20**

and semiconductor element **8***a* are performed. In addition thereto, implant pins **20** and cylindrical terminals **10** are bonded to each other by sintering of sinter material **29**.

The heating temperature in the reflow time is preferably not higher than 350° C., more preferably in the range of from 250° C. to 330° C. When the heating temperature is higher than 350° C., there is a fear that the semiconductor elements etc. may be thermally damaged.

External terminals **9** are disposed in predetermined positions of metal layer **5** through the solder or sinter material layer **7***b*. When the solder or sinter material layer **7***b* is melted or sintered, metal layer **5** and external terminals **9** are bonded to each other. Further, cooling plate **1** is surrounded by resin casing **2**. The internal portion enclosed by resin casing **2** is filled with the sealing resin **15**. The sealing resin is hardened. In this manner, the semiconductor device is manufactured.

Thus, a semiconductor device and a method for manufacturing the same have been described according to the present invention. Many modifications and variations may be made to the techniques and structures described and illustrated herein without departing from the spirit and scope of the invention. Accordingly, it should be understood that the methods and devices described herein are illustrative only and are not limiting upon the scope of the invention.

REFERENCE SIGNS LIST

1: cooling plate
2: resin casing
3: insulating wiring board
4: insulating substrate
5, **6**: metal layer
7*a*, **7***b*, **7***c*, **7***d*, **7***e*: solder or sinter material layer
8, **8***a*, **8***b*: semiconductor element
9: external terminal
10: cylindrical terminal
15: sealing resin
20: implant pin
28: plating layer
29: sinter material
30: implant board
31: insulating substrate
32, **33**: metal layer
34: insulating wiring board
35: via hole
36: bonding material
51: cooling plate
52: resin casing
53: insulating substrate
54, **55**: metal layer
56: insulating wiring board
58: semiconductor element
59: external terminal
60: bonding wire
61: sealing resin
71: insulating substrate
72, **73**: metal layer
74: via hole
75: insulating wiring board
76: implant pin
79: implant board

What is claimed is:

1. A semiconductor device comprising:

a semiconductor mounting board in which a plurality of semiconductor elements are mounted on an insulating wiring board, the semiconductor mounting board having a circuit pattern;

an implant board in which via holes for electrical connection are provided in an insulating substrate having a printed wiring, and

implant pins, first ends of which are press-fitted into the via holes and second ends of which are bonded to the semiconductor element and/or the circuit pattern of the semiconductor mounting board such that there is an electrical connection to the semiconductor element of the semiconductor mounting board,

wherein distance between (i) the implant board and (ii) the semiconductor elements and/or the circuit pattern of the semiconductor mounting board varies, and

wherein the implant pins are bonded to the semiconductor element and/or the circuit pattern of the semiconductor mounting board through cylindrical terminals press-fitted onto the second ends of the implant pins, and in the semiconductor device a depth with which each of the implant pins is press-fitted into corresponding ones of the cylindrical terminals varies so that total length of the implant pin and the cylindrical terminal which are press-fitted to each other match up with a distance between the semiconductor element and/or the circuit pattern on the semiconductor mounting board and the implant board.

2. A semiconductor device according to claim **1**, wherein a plating layer is provided on a surface of a press-fitting portion of each of the implant pins and/or on an inner circumferential surface of the cylindrical terminal, such that the plating layer bonds the implant pin press-fitted into the cylindrical terminal to the cylindrical terminal when the plating layer is heated and melted.

3. A semiconductor device according to claim **1**, wherein a sinter material is on a surface of a press-fitting portion of each of the implant pins and/or on an inner circumferential surface of the cylindrical terminal, such that the sinter material bonds the implant pin press-fitted into the cylindrical terminal to the cylindrical terminal when the sinter material is heated.

4. A semiconductor device according to claim **1**, wherein each of the implant pins contacts at least 40% of an inner circumference of a corresponding cylindrical terminal in a section perpendicular to the implant pin in a contact portion between the implant pin and the inner circumferential surface of the cylindrical terminal.

5. A semiconductor device according to claim **1**, wherein a protruding portion protruding over an outer circumference of each of the implant pins is provided in a press-fitting portion of the implant pin corresponding to one of the cylindrical terminals by drawing so that the protruding portion can come into contact with an inner circumferential surface of the cylinder terminal.

6. A semiconductor device according to claim **5**, wherein a value obtained by subtracting an inner diameter of each of the cylindrical terminals from a largest diameter of a press-fitting portion of corresponding one of the implant pins is in the range of from 0 to 0.25 mm.

7. A semiconductor device according to claim **1**, wherein a straight columnar portion which has not been subjected to drawing is provided in a press-fitting portion of each of the implant pins, so that at least a part of the columnar portion contacts an inner circumferential surface of a corresponding cylindrical terminal.

8. A semiconductor device according to claim **7**, wherein a value obtained by subtracting an inner diameter of each of the cylindrical terminals from a largest diameter of a press-fitting portion of corresponding one of the implant pins is in the range of from 0 to 0.15 mm.

9. A semiconductor device according to claim **1**, wherein each of the implant pins has a tapered end on the cylindrical terminal side, so that the implant pin has a diameter which decreases toward the end.

10. A semiconductor device according to claim **1**, wherein an inner circumference of each of the cylindrical terminals has a shape which matches up with a press-fitting portion of a corresponding implant pin.

11. A semiconductor device according to claim **1**, wherein the implant pins comprise a first pin and a second pin having substantially the same length, wherein the second end of the first pin is bonded to the semiconductor element and the second end of the second pin is bonded to the semiconductor element and/or the circuit pattern of the semiconductor mounting board through the cylindrical terminals.

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